On-Line High Dose-rate Gamma Irradiation Test of the Profibus/DP module

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1. Introduction

The field bus data communication is considered for application in nuclear environments. The nuclear facilities, including nuclear power plants, high radioactivity waste disposals, reprocessing plants and thermonuclear fusion installations can benefit from the unique advantages of the field bus communication network for the smart field instruments and controls. A major problem which arises when dealing with one in these nuclear environments, in special circumstances such as the RCS (reactor coolant system) area, is the presence of high gamma-ray irradiation fields [1]. Radioactive constraints for the DBA(design basis accident) qualification of the RTD transmitter installed in the inside of the RCS pump are typically on the order of 4kGy/h with total doses up to 10kGy[2]. In order to use an industrial field bus communication network as an ad-hoc sensor data link in the vicinity of the RCS area of the nuclear power plant, the robust survivability of these system in such intense gamma-radiation fields therefore needs to be verified. We have conducted high dose-rate (up to 4kGy) gamma irradiation experiments on a profibus/DP communication module. In this paper we describe the evolution of its basic characteristics with high dose-rate gamma irradiation and shortly explain the observed phenomena.

2. Experiment

A block diagram of a typical gamma irradiation set up for the profibus/DP communication module is shown in Fig. 1.

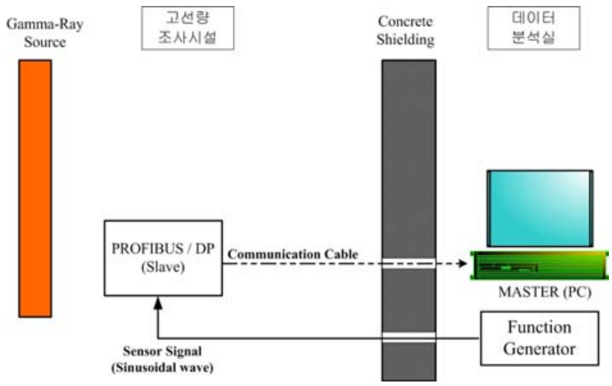


Fig. 1. A schematic diagram of the gamma irradiation test

In order to evaluate data transmission characteristics of profibus/DP communication module, function generator was used as the sensor signal source. The function generator transmits sinusoidal wave to profibus module via coaxial cable. The profibus/DP slave module captures analog-typed sinusoidal wave signal, and converts digital-typed profibus signal protocol with embedded A/D module and communication protocol conversion algorithm in the memory. The profibus/DP module resends the converted profibus protocol signal (digital-typed) via communication cable to profibus master interface card, embedded in the notebook PC. The profibus master recovers the sensor signal transmitted by function generator. Comparing the function generator signal and the recovered sensor signal, high dose-rate gamma radiation induced degradation of the profibus/DP communication module is easily observed.

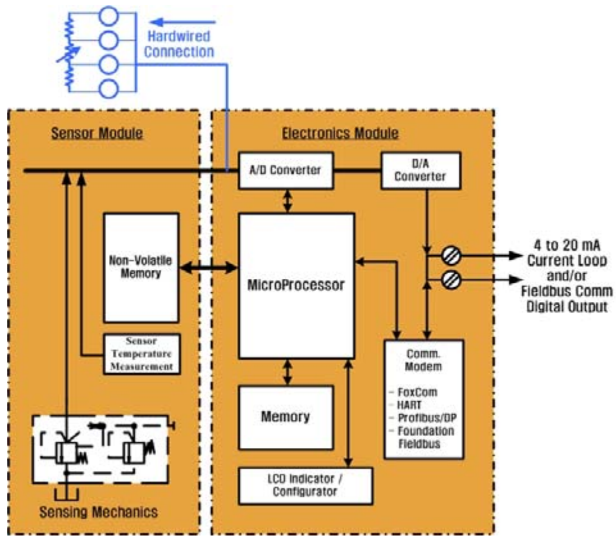


Fig. 2. Architecture of field bus communication module

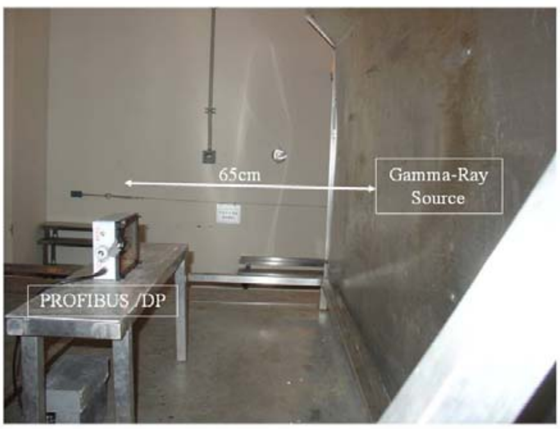


Fig. 3. A profibus/DP field bus communication module placed in the high dose-rate gamma irradiation facility.

The experimental setups for gamma irradiation test for the profibus/DP are shown in Fig. 3 and 4. Fig. 5 shows gamma irradiation cycle of the profibus/DP module.

(a) Profibus/DP communication module

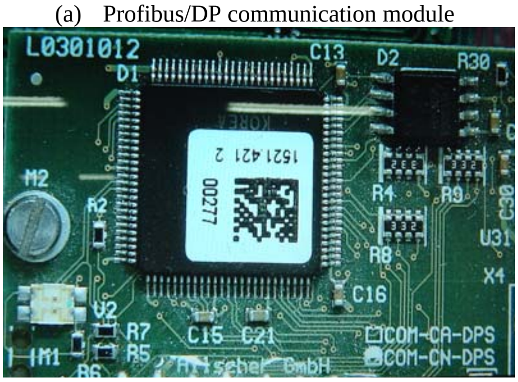


Fig. 4. (b) Profibus chipset (Hilscher GmbH)

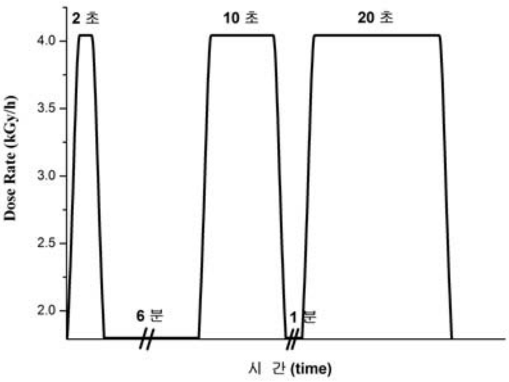
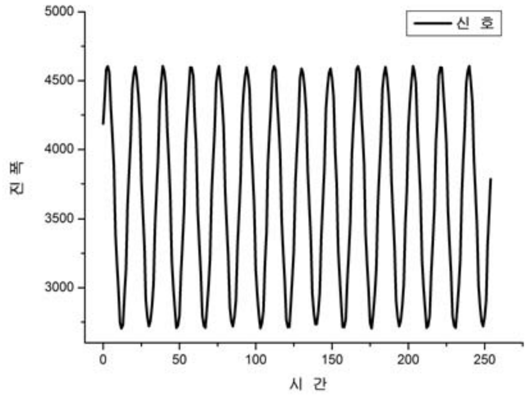


Fig. 5. Gamma irradiation cycle for the profibus/DP module

Fig. 6 shows on-line observation waveform of the profibus/DP module. Fig. 6(a) shows normal observation waveform. And Fig. 6(b) shows deformed waveform after 10 seconds at the 3rd cycles shown in Fig. 5 during high dose-rate gamma irradiation. It is estimated that the A/D conversion module embedded in the module is damaged. The more sophisticated analysis of the damaged parts of the module is underway. From the view point of the TID (24Gy) dose, the discrete parts of the profibus/DP communication module should survive at that low dose. Generally CMOS FPGA chipsets are survival up to 1kGy TID dose. In order to design and fabricate the field bus communication module for the RCS area application, the discrete devices and parts are needed to pass the RLAT (radiation lot acceptance test) test. If the Si-CMOS FPGA chip, functioned as A/D conversion driver, is effectively shielded by lead material (about 8.4mm thickness at the 1MeV gamma-ray source), the profibus /DP module will show survivability in the gamma-irradiation requirement during design base accidents.



(a) Normal waveform

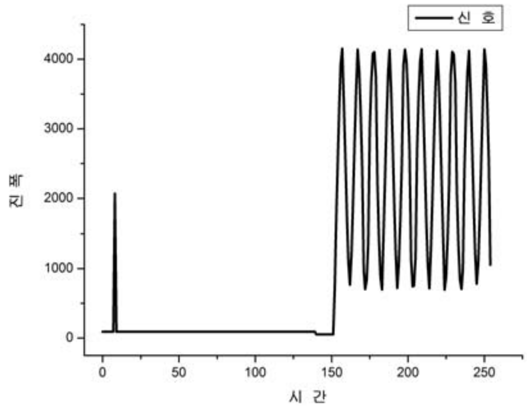


Fig. 6. (b) Deformed waveform after gamma irradiation.

3. Conclusions

In order to use the field bus communication system as an ad-hoc sensor data link in the vicinity of the RCS area of the nuclear power plant, the robust survivability of its system in such intense gamma-radiation fields needs to be assured. We have conducted high dose-rate (up to 4kGy) gamma irradiation experiments on a industrial field bus module for the profibus data link. The evolution of its basic characteristics with high dose-rate gamma radiation field and the observed phenomena were described in this paper. If the Si-CMOS FPGA and ASIC chip set, functioned as the profibus protocol driver, is effectively shielded by lead material (about 8.4mm thickness at the 1MeV gamma-ray source), it is concluded that the field bus communication module can be survived robustly in the gamma-irradiation requirement during design base accidents.

REFERENCES

[1] R.E. Sharp, "Radiation effects on electronic equipment, a designers'/users' guide for nuclear power industry", AEA-D&W-0691, 1994

[2] Weed Instrument, "Nuclear Qualified N4000R-99 Series RTD Temperature Transmitter", Datasheet